# BEAM DYNAMICS REDESIGN OF IFMIF-EVEDA RFQ FOR A LARGER INPUT BEAM ACCEPTANCE

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*Abstract*

For the IFMIF-EVEDA RFQ (a very challenging deuteron CW RFQ at 175 MHz from 0.1 MeV to 5 MeV with 125 mA of current), the input beam characteristics are very important. A lower focusing force in the first part of the RFQ has been implemented in order to reduce the requirements of the input beam. In the article a full description of the new design will be reported with the changes in the RFQ performances.

## INTRODUCTION

The RFQ of IFMIF-EVEDA project is characterized by very challenging specifications, with 125 mA of deuteron CW accelerated up to 5 MeV [1]. After the period of conceptual and comprehensive design of IFMIF accelerator, the detailed design review of the project has shown the difficulty on the beam input characteristics and this has implied a new analysis on the RFQ transverse design. This new design with a lower transverse focusing force permits a larger safety margin in the RFQ operation at the cost on the slight reduction on the RFQ performance and a longer zone with full 3D electrode modulation.

## CHANGE ON DESIGN

IFMIF RFQ is a long structure composed by 18 modules (three supermodules of 6 modules each); the production of the modules has started in spring 2010 from the high energy supermodule before the final decision about the low energy end modulation.

The physical design method of the RFQ is reported in [2], [3]. The change on the initial focusing force is done by keeping a prefixed distance between the transverse phase advance and the longitudinal one, see fig. 1, the effect is a gradual increase in the focusing force "B" of the RFQ from the input value of 4 to the "old" value of 7, this is done in the shaper section of the RFQ. The Gentle buncher and the accelerator section of the RFQ are unchanged, that produce the same longitudinal beam dynamics, i.e. is not influenced by the changing of B along the shaper section, the longitudinal emittance with the low B, has the same value as for the original design.

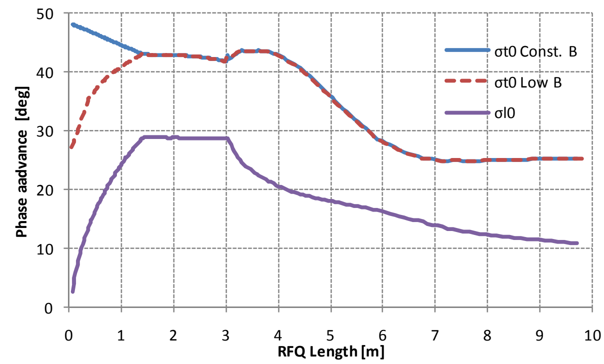


Figure 1: Comparison of phase advance at zero current for the constant B RFQ, and for the low B RFQ.

The resulting new parameters are reported in table 1 and Fig. 2.

Table 1: RFQ Main Parameters

| | | |
|---|---|---|
| Length | 9.814 | m (5.7 λ) |
| Total Cell number | 489 | |
| Voltage Min/Max | 79.29/132 | kV |
| Max modulation m | 1.7987 | |
| Min aperture "a" | 3.47573 | mm |
| R0 min/Max | 5.476 / 7.102 | mm |
| Ratio ρ/R0 (constant) | 0.75 | |
| Final Syncronous phase | -33.5 | Deg |
| Total RF Power+Beam power | 1.6 | MW |
| Transmission (Gaussian) | 93.7 | % |
| Longitudinal Emittance RMS | 0.2 | MeV deg |
| In/Out Tr. Emittance RMS | 0.25/0.26 | mm mrad |
| Beam Power Loss (Gaussian) | 1291 | Watts |
| Max Surface Field (1.76 Kp) | 24.7 | MV/m |

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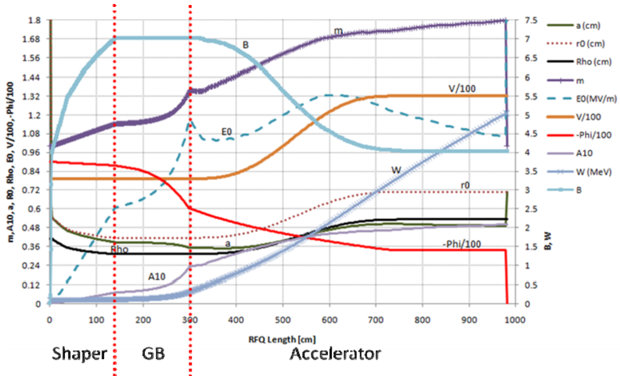


Figure 2: Main parameters evolution along the RFQ.

The law imposed on the phase advance, changes by consequence also the tip radius, which is kept with a constant ratio of 0.75 respects to the average aperture.
All the other parameters along the RFQ result unchanged.

### *Input Beam Parameters*

The input Twiss parameters for the nominal matched beam of 130 mA and a RMS emittance of 0.25 mmmrad norm. are reported on table 2. It appear that with a low focusing at the RFQ input is less demanding the optics from the last solenoid to the RFQ entrance. A study has been done to check that, and the study show a larger zone of stable results respect to the solenoid field values of about a factor 2 [4].

Table 2: Input Beam

| | Constant B | Low B | |
|---|---|---|---|
| Alfa | 3.03 | 1.3 | |
| Beta | 0.135 | 0.109 | m/rad |
| RMS Beam Size | 1.81 | 1.63 | mm |
| RMS Beam div. | 42.71 | 24.36 | mrad |

The most important figure is that for the low B RFQ, the divergence of the input beam is smaller by a factor 2. This reduces the requirements for the solenoids and for the mechanical design of the dense input LEBT RFQ interface. The density plot size of the beam is reported in Fig. 3, the blue colour density is in the order of $10^{-5}$ beam intensity, i.e. 6 W, and the losses are coloured of black.

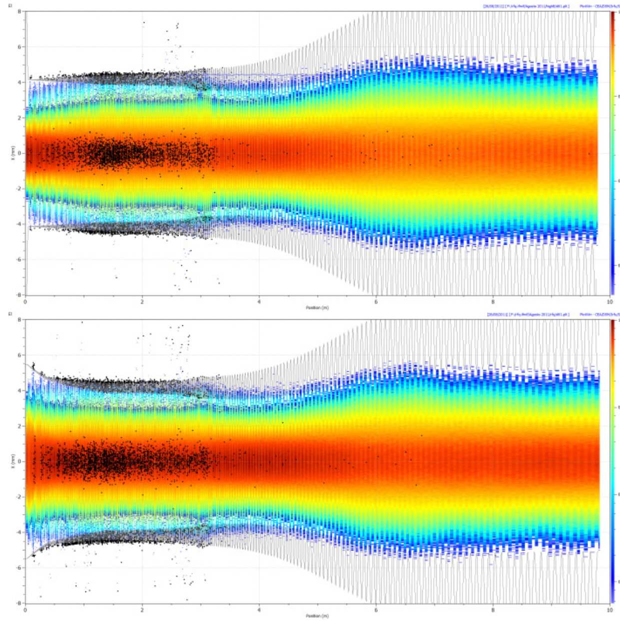

Figure 3: Particles density plot on transverse plane X along the RFQ, for the constant B case, upper plot, and the low B case, lower plot.

## PERFORMANCE COMPARISON

The Low B RFQ has been simulated with the TraceWin/Toutatis code to check the beam quality; the input distribution used is Gaussian to populate more the tails of the beam, this distribution also have a very large ratio of total emittance to RMS emittance of 16. The comparison of the two RFQ results are very similar, there is only a small degradation on the transmission on the low B RFQ. The beam power losses in both cases are quite similar, 1.3 kW for the low B and 1.1 kW for the constant B RFQ, see Fig. 4.

The transmission is reduced in the Low B RFQ of about 1.5% due to the slightly larger beam dimensions, but in the low energy part of the RFQ; this is merit of the "scraper" zone at the end of Gentle Buncher, to stop the particles not accelerated, Fig. 5.

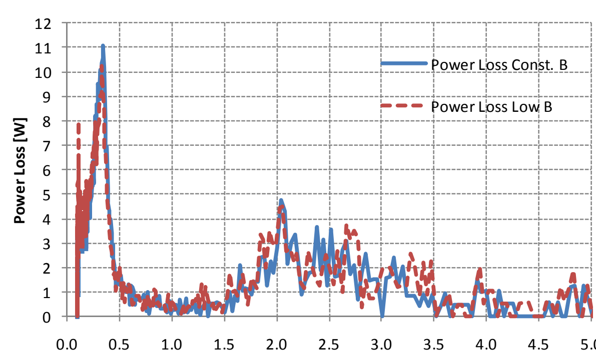


Figure 4: Power Loss as function of the energy.

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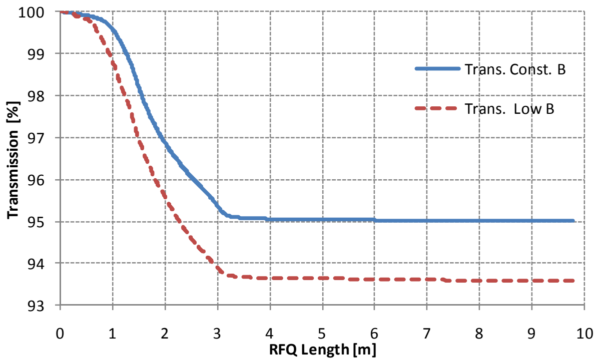


Figure 5: Transmission along the RFQ.

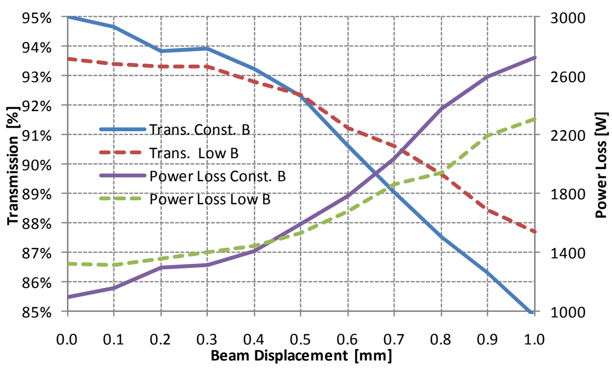


Figure 6: Transmission and power loss as function of beam displacement for the Constant B and the low B RFQ.

The sensitivity to the input beam position is less demanding for the low B RFQ, i.e. is possible to avoid large losses also with beam displaced of more than 0.5 mm, see Fig. 6.

The beam mismatch do not impact in different way for the two RFQ, in both cases the RFQs, support more than 10% mismatch, calculated as a multiplicative factor for both alpha and beta Twiss parameters, see Fig. 7.

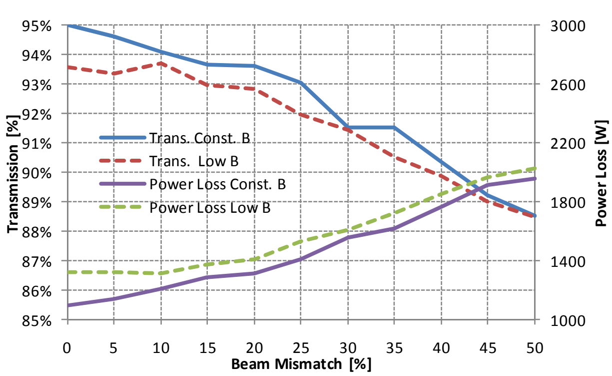


Figure 7: Transmission and power loss as function of the beam mismatch.

The input emittance on the two RFQs, produce very similar results, practically the constant B RFQ, for a fixed transmission, can accept a larger emittance, see Fig. 8.

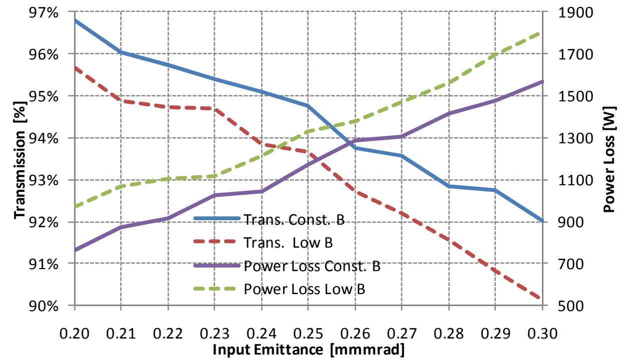


Figure 8: Transmission and power loss as function of the input emittance.

## CONCLUSION

The main advantage of the low B solution is in terms of requirements of the LEBT and easy tuning of the input beam; to achieve this results the RF design and the mechanics of the first two supermodules has been modified in short time just before the beginning of the production. The modified design costs in term of RFQ performances is about 2% in transmission and about 5% on the emittance acceptance, but allows an easier setting at the LEBT-RFQ interface.

## REFERENCES

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